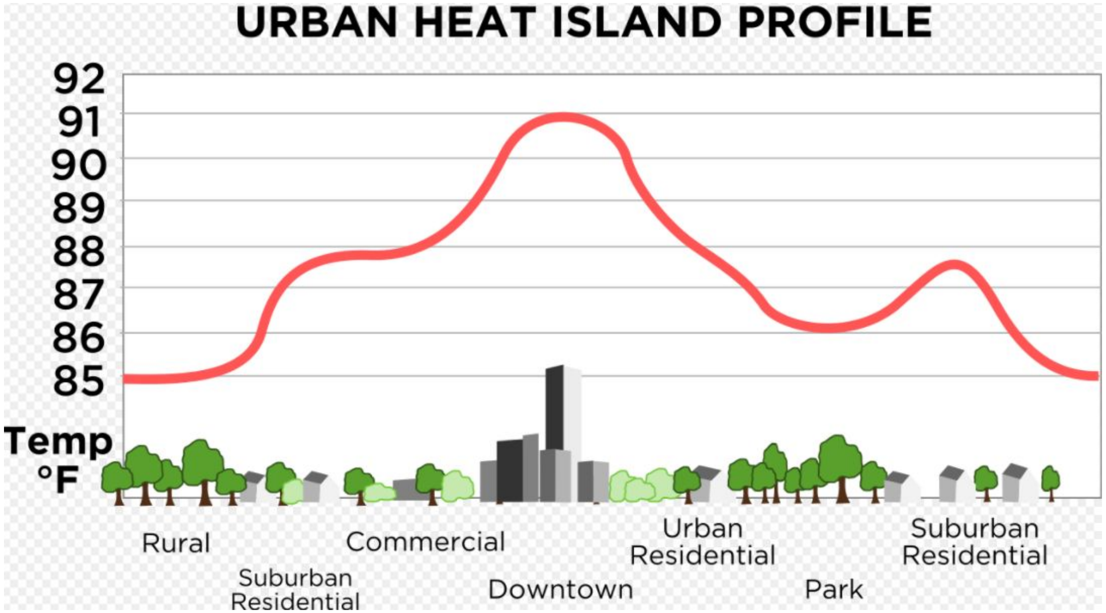
Cooling Cities



Investigating different urban surfaces and their impacts on the Urban Heat Island Effect

Left:
https://en.wikipedia.org/wiki/Urban_heat_island#/media/File:Urban_heat_island.svg
Right:https://climatekids.nasa.gov/heat-islands/

All photos, graphs, and images created by researcher unless indicated otherwise

Background

- The rapid increase of human population and cities through the 20th into the 21st centuries have altered the Earth’s climate in numerous significant ways.
- A major environmental issue that developed during this time as human population and growth of cities skyrocketed were Urban Heat Islands (UHI), an increase of temperatures in urban areas compared to their rural counterparts.
- Above 90.F, just an increase of one degree can significantly increase the risk of heat exhaustion; 600 heat related deaths annually in the United States (CDC)
- Average number of heatwaves tripled since 1960; urban heat islands can further extrapolate the intensity of these heat waves (EPA)
- This increase of temperature can contribute to more heat related deaths in urban areas, as Urban Heat Islands largely affect inner city areas where many residents can't afford things like air conditioning- 47% of Detroit does not have AC (Planet Detroit).
- Wanted to identify a cost effective material that could be used in urban areas to help mitigate this effect

Research Question

Which type of common pavement material used in urban areas contributes the least to the Urban Heat Island effect?

Previous studies: Numerous studies done on Urban Heat Islands as a whole, but limited research on which specific materials contribute the greatest to this effect with emphasis on urban pavements

-2020 study on Urban Heat Island impacts (CM Nwakaire)

-Discussed how to adopt effective mitigation strategies to urban pavement to mitigate the effects of Urban Heat Islands in cities

-Few solutions proposed in this study included adopting vegetated, water retentive, permeable, heat harvesting, or reflective pavements.

-Studies done of urban heat islands as a whole agree that asphalt and concrete contribute the greatest to this effect

- I think one of the brick surfaces will contribute the least to Urban Heat Islands

Procedure- Overview

- No way to measure temperature of a surface without a surface temperature recorder (similar to thermometers used to measure body temperature by recording forehead temp)
- Instead placed a mix of salt and water on each of the five surfaces I was testing (asphalt concrete, light concrete, red brick, brick) and attempted to measure the temperature chance of this saltwater mix to carry over to see which of the five surfaces overall least temperature change (added salt to water to lower freezing point)
- To measure temperature change over a period of time, I created a device with a mix of water and rubbing alcohol and placed a straw within it which would fluctuate with different levels of water-alcohol solution depending on the temperature
- This is because heating causes expansion, pushing the level of solution in the straw higher, and cooling causes contraction, bringing the water level down
- My independent variable was time and my dependent variable was the height of solution within the straw in my device (cm)
- Variables I controlled were length of time I was recording data (24 hours), time of day I was recording data (all 5 surfaces were tested at the same time), the medium I used to measure temperature change (placed a container with 150ml water and 10g salt on all five surfaces and dipped my devices in these solutions), the amount of water and rubbing alcohol I used in my solution in device (100ml each across all 5 devices)
- I attempted to measure the change in the level of solution in the straw across 24 hours

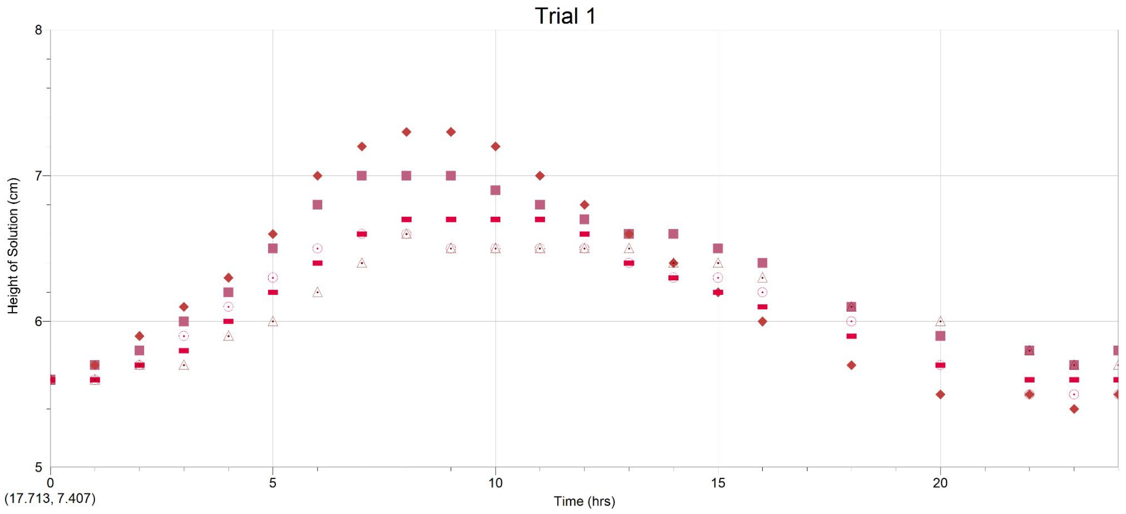
Procedure- Building My Device

1. Wear all safety equipment (goggles)
2. Mix 100 ml of distilled water with 100ml of 70% rubbing alcohol into a bottle or glass container (only requirement is that it is somewhat narrow)
3. Add two drops of food coloring to the bottle and mix (any color)
4. Place a transparent straw into the bottle until it is nearly submerged (ensure that the straw doesn’t touch the bottom of the bottle)
5. Wrap modeling clay to the top of the bottle to seal the bottle and hold the straw in place; wrap modeling clay around the top of the straw as well
6. Repeat steps 1-5 to create 4 more bottles

Procedure- Collecting Data

1. Fill five clear plastic containers with 100ml cold water + mix in 14 g of salt and place outside the previous night to let the water get accustomed to the outdoor temperature. (This will lower freezing point to about 18.F)
2. The next morning (7am), place each device in the plastic containers filled with the cold water and record the level of the solution within the device. (It should be more or less the same)
3. Place each plastic container WITH the device on a different surface (asphalt, light concrete, darker concrete, brick, red brick).
4. Record the level of the solution within the device every hour for 24 hours (until next morning at 7am) and enter data in a table.
5. Model the data on a graph for analysis

Analyzing Data- Trial 1



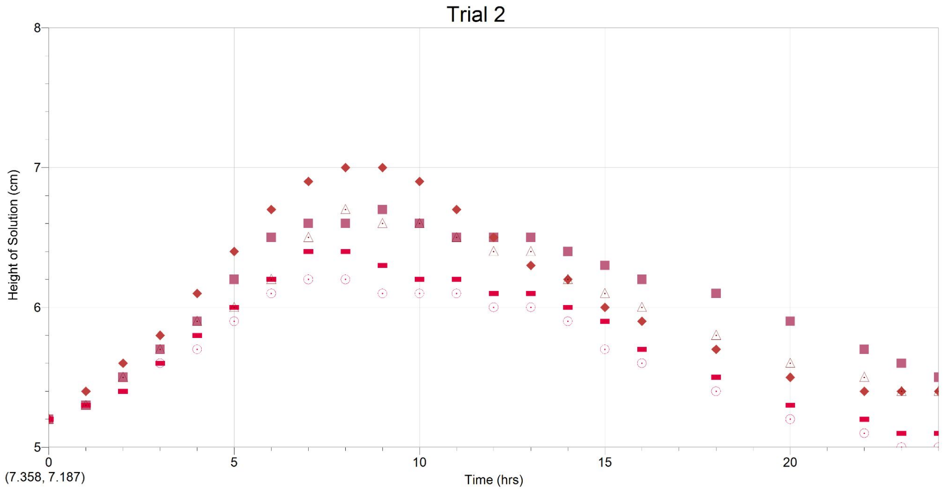
Key:

Triangle= Concrete 2
Circle= Red Brick
Rectangle= Brick
Square= Concrete
Diamond= Asphalt

From my data in Trial 1, I can conclude that asphalt reached the highest temperature as it had the highest peak of the height of solution than all other pavement materials. Red Brick had the lowest peak as can be seen in the table and graph, showing that this surface reached a lower temperature than the other surfaces throughout the day. This shows that asphalt absorbed heat the fastest, while red brick absorbed heat the slowest. The next morning, interestingly, both red brick and asphalt surfaces had the lowest amount of solution left in the straw. This shows that both these materials are good heat releasers as well.

	Red Brick		Concrete		Asphalt		Brick		Concrete 2	
	Time (hrs)	y	Time (hrs)	y	Time (hrs)	y	Time (hrs)	y	Time (hrs)	y
1	0	5.6	0	5.6	0	5.6	0	5.6	0	5.6
2	1	5.6	1	5.7	1	5.7	1	5.6	1	5.6
3	2	5.7	2	5.8	2	5.9	2	5.7	2	5.7
4	3	5.9	3	6	3	6.1	3	5.8	3	5.7
5	4	6.1	4	6.2	4	6.3	4	6	4	5.9
6	5	6.3	5	6.5	5	6.6	5	6.2	5	6
7	6	6.5	6	6.8	6	7	6	6.4	6	6.2
8	7	6.6	7	7	7	7.2	7	6.6	7	6.4
9	8	6.6	8	7	8	7.3	8	6.7	8	6.6
10	9	6.5	9	7	9	7.3	9	6.7	9	6.5
11	10	6.5	10	6.9	10	7.2	10	6.7	10	6.5
12	11	6.5	11	6.8	11	7	11	6.7	11	6.5
13	12	6.5	12	6.7	12	6.8	12	6.6	12	6.5
14	13	6.4	13	6.6	13	6.6	13	6.4	13	6.5
15	14	6.3	14	6.6	14	6.4	14	6.3	14	6.4
16	15	6.3	15	6.5	15	6.2	15	6.2	15	6.4
17	16	6.2	16	6.4	16	6	16	6.1	16	6.3
18	18	6	18	6.1	18	5.7	18	5.9	18	6.1
19	20	5.7	20	5.9	20	5.5	20	5.7	20	6
20	22	5.5	22	5.8	22	5.5	22	5.6	22	5.8
21	23	5.5	23	5.7	23	5.4	23	5.6	23	5.7
22	24	5.5	24	5.8	24	5.5	24	5.6	24	5.7

Analyzing Data- Trial 2



Key:

Triangle= Concrete 2
Circle= Red Brick
Rectangle= Brick
Square= Concrete
Diamond= Asphalt

From my data in Trial 2, I can conclude that asphalt once again reached the highest temperature as it had the highest peak of the height of solution than all other pavement materials. Red Brick and Brick surfaces had one the lowest peaks as can be seen in the table and graph, showing that these surfaces reached a lower temperature than the other surfaces throughout the day. This shows that asphalt absorb heat the fastest, while red brick and brick surfaces absorbed heat the slowest. The next morning both the brick surfaces had the lowest amount of solution left in the straw. This shows that both these materials are good heat releasers as well.

	Red Brick		Concrete		Asphalt		Brick		Concrete 2	
	Time (hrs)	y	Time (hrs)	y	Time (hrs)	y	Time (hrs)	y	Time (hrs)	y
1	0	5.2	0	5.2	0	5.2	0	5.2	0	5.2
2	1	5.3	1	5.3	1	5.4	1	5.3	1	5.3
3	2	5.5	2	5.5	2	5.6	2	5.4	2	5.5
4	3	5.6	3	5.7	3	5.8	3	5.6	3	5.7
5	4	5.7	4	5.9	4	6.1	4	5.8	4	5.9
6	5	5.9	5	6.2	5	6.4	5	6	5	6
7	6	6.1	6	6.5	6	6.7	6	6.2	6	6.2
8	7	6.2	7	6.6	7	6.9	7	6.4	7	6.5
9	8	6.2	8	6.6	8	7	8	6.4	8	6.7
10	9	6.1	9	6.7	9	7	9	6.3	9	6.6
11	10	6.1	10	6.6	10	6.9	10	6.2	10	6.6
12	11	6.1	11	6.5	11	6.7	11	6.2	11	6.5
13	12	6	12	6.5	12	6.5	12	6.1	12	6.4
14	13	6	13	6.5	13	6.3	13	6.1	13	6.4
15	14	5.9	14	6.4	14	6.2	14	6	14	6.2
16	15	5.7	15	6.3	15	6	15	5.9	15	6.1
17	16	5.6	16	6.2	16	5.9	16	5.7	16	6
18	18	5.4	18	6.1	18	5.7	18	5.5	18	5.8
19	20	5.2	20	5.9	20	5.5	20	5.3	20	5.6
20	22	5.1	22	5.7	22	5.4	22	5.2	22	5.5
21	23	5	23	5.6	23	5.4	23	5.1	23	5.4
22	24	5	24	5.5	24	5.4	24	5.1	24	5.4

Analysis

- Through the two trails, asphalt conducted heat the best as seen by the highest peak. This supports my hypothesis that asphalt would have the greatest impact to Urban Heat Islands as it would be the best material to trap in heat.
- Through both the trials, it was clear that the asphalt and concrete surfaces contribute greater to urban heat islands as they had significantly higher peaks than the brick surfaces
- Despite asphalt being a very good heat absorber, it actually released heat faster than the concrete materials as seen by a lower minimum level of solution the next morning
- Red brick surfaces overall contribute the least to Urban Heat Islands as they were relatively slow heat absorbers and fast heat releasers as seen by the lowest peaks and one of the lowest minimum level of solution in the straw the next morning across both trials
- These findings support previous studies concluding that asphalt and concrete are the worst pavement materials
- These findings support my hypothesis that a brick surface would contribute the least to Urban Heat Islands

Conclusion

Red brick surfaces contribute the least to the Urban Heat Island effect by having slower heat absorption and fairly less heat retention than all other surfaces. During the procedure, the alcohol-water solution within my device changed the least for red brick surfaces. This can be seen with the data modeling red brick surfaces having a lower slope to a peak that is lower than all the other surfaces (as seen in the table), and are good heat releasers as seen by the lowest peaks and one of the lowest minimum level of solution in the straw the next morning across both trials (as seen in the table).

This research can be used by urban developers when considering which surfaces to use in cities that are environmentally friendly, but also cost friendly as all the materials that I tested are not expensive to implement. Urban developers could consider implementing more red brick surfaces such as sidewalks and roads in downtown areas, where it could be aesthetically pleasing, while simultaneously contributing less to Urban Heat Islands than asphalt and concrete.

Errors + Limitations + Ideas for Future Research

- Shadows were affecting each test site at different times- this could have affected the data
- The weather on the two trails I ran my procedure was different which caused the data to vary between observations of the two trails (Weather was warmer and sunny on the day of trail 1, trail 2 was cooler and there were more clouds in the sky)
- Wasn't directly measuring surface ability to absorb heat as the experiment actually measured the change in temperature of saltwater on each pavement material (water absorbs heat slower than land and retains heat longer; however, this became a control since I followed this method for all pavement surfaces)
- In the future, pavement materials can be tested under artificial light indoors, which would eliminate any shadows or other outside variables
- Using a surface temperature monitor, such as the ones used to measure human body temperature by using the forehead temperature can help data be much more precise and allow us to have better quantitative data

References

https://www.epa.gov/heatislands/learn-about-heat-islands

https://scied.ucar.edu/learning-zone/climate-change-impacts/urban-heat-islands

https://www.scientificamerican.com/article/measure-up-with-a-homemade-thermometer/

https://www.cdc.gov/disasters/extremeheat/index.html

https://www.epa.gov/climate-indicators/climate-change-indicators-heat-waves

https://planetdetroit.org/2021/06/researchers-predict-a-combined-heatwave-and-blackout-event-in-detroit-could-be-worse-than-katrina-heres-why/

Nwakaire, Chidozie Maduabuchukwu, et al. "Urban Heat Island Studies with Emphasis on Urban Pavements: A Review." Sustainable Cities and Society, Elsevier, 7 Sept. 2020, https://www.sciencedirect.com/science/article/abs/pii/S221067072030696X.